NATURAL GAS AS A PATHWAY TO DE-CARBONIZING TRANSPORTATION FUELS *

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Natural gas vehicles offer greenhouse gas reductions of twenty to thirty percent at the tailpipe compared to gasoline and diesel vehicles. However, policymakers in California have committed the state to a reduction in greenhouse gas emissions of eighty percent by 2050 compared to 1990 levels. This is often cited as a reason to pursue vehicle electrification for the California market. The explanation for this perspective is that since these vehicles offer a pathway to zero-emissions on a full life cycle basis, assuming that the electricity they consume is generated using renewable sources.

Natural gas vehicles can also help provide a transition to a zero-carbon transportation system. The abundance of domestic reserves of natural gas assures that it can reliably supply transportation energy for decades to come. At the same time, investments made in a natural gas vehicle fueling infrastructure can continue to deliver value in the long-term, even under the most stringent future constraints on greenhouse gas emissions. Renewably-derived methane and hydrogen are potential transportation fuels that can benefit from a network built to serve natural gas vehicles.

Renewable Natural Gas Renewable natural gas, or biomethane, results from anaerobic digestion of organic matter, such as municipal solid waste or animal waste. Once biomethane is purified and either compressed or liquefied, it can be used interchangeably with conventional natural gas for all end uses, including in the production of CNG and LNG to fuel natural gas vehicles.

In the United States, conversion of landfill gas to natural gas fuel been demonstrated in California and New Jersey and is now being implemented on a commercial scale in several locations around the country.[1] In Europe, renewable natural gas has been the European Parliament's target of 10 percent biofuel use in transport by 2020[2].

In the United States, biomethane qualifies as an advanced biofuel under the expanded Renewable Fuel Standard (RFS II) included in the Energy Independence and Security Act of 2007.[3] The RFS II establishes a minimum volume of biofuels to be blended into the motor fuel stock consumed in the nation's transportation sector. Since other forms of advanced biofuels, such as cellulosic ethanol, have not achieved commercial scale to date, the RFS II provides an added economic incentive for the use of renewable gas as a motor fuel. Because of low prices of conventional natural gas, the cost of renewable gas production in most cases is still uneconomic, even with the added revenue stream provided by sale of credits toward compliance with the RFS II.

Clean Energy, a commercial firm that owns and operates CNG and LNG refueling stations across the United States, formed a subsidiary, Clean Energy Renewable Fuels, to develop the potential of renewable natural gas as a low-emissions fuel for fleet vehicles. One of its key holdings is the McCommas Bluff landfill in Texas, the third largest landfill gas operation

[1] Locations of commercial sites include Columbus, OH; Dallas, TX; Orange County, Sonoma County, and Livermore, CA; Oklahoma City, OK; and DeKalb County, GA.
[2] European Commission, An EU Strategy for Biofuels, Communication from the Commission, COM(2006) 34, 2006.
[3] Energy Independence and Security Act of 2007, P.L. 110-140.

in the United States. The plant has a capacity of about 36,000 gasoline gallon equivalents (gge) per day of pipeline quality methane. The company has announced plans to increase capacity to 60,000 gge per day.

Clean Energy Renewable Fuels has also announced plans to produce biomethane captured from the Sauk Trail Hills Landfill site in Canton, Michigan. Clean Energy will build a high-BTU landfill gas processing plant for injection into the natural gas pipeline system. The renewable natural gas will be distributed for vehicle fuel use to local natural gas fleets, Clean Energy customers and direct use by renewable power customers. Clean Energy estimates biomethane output of 6 million diesel gasoline gallon equivalents annually when the processing facility is fully operational.[4]

<u>Natural Gas Vehicles as a Pathway to Hydrogen Fuel Cell Vehicles</u>. Deployment of natural gas vehicles and infrastructure will likely be a key pathway toward the adoption of hydrogen fuel cell vehicles. Natural gas and of hydrogen similar challenges as transportation fuels. Because both fuels are gaseous, they have similar requirements for distribution, storage, and dispensing at fueling stations. Onboard the vehicle, fuel storage and fuel management systems require corresponding technologies. Safety standards and training programs for hydrogen can be derived from lessons learned through the safe operation of natural gas vehicles and fueling technologies.

[4] Clean Energy Renewable Fuels, various press releases, available at http://www.cleanenergyfuels.com/company/renewablefuels.html.

There are additional potential synergies. Natural gas is the preferred feedstock for hydrogen production today and is likely to remain so for several decades.[5] Methane, the key constituent of natural gas, is made up of 20 percent carbon atoms and 80 percent hydrogen atoms. This high percentage of hydrogen content makes it an excellent feedstock for producing hydrogen gas.

A national network of natural gas fueling stations could evolve to include hydrogen fueling as well; through on-site reformation of natural gas to hydrogen. Existing natural gas pipelines could be retrofitted with hydrogen-compatible liners where needed, converting the natural gas distribution infrastructure to a hydrogen distribution infrastructure as appropriate. In locations where separate hydrogen pipelines are required, existing rights-of-way for natural gas pipelines could facilitate placement. Natural gas and hydrogen mixtures are also a viable vehicle fuel. Introducing small amounts (a few percent) of hydrogen to natural gas has been demonstrated to enhance vehicle performance and reduce greenhouse gas emissions.[6] Few modifications are needed to add a hydrogen-enriched natural gas option to an existing CNG station.

As a further interim step towards hydrogen, natural gas-hydrogen blends of twenty to thirty percent hydrogen by volume are compatible with most natural gas vehicle engines,

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[5] In the longer term, electrolysis of water using electricity generated by renewable could offer a zero-carbon pathway for hydrogen production. This production method is not economic today compared to steam reformation of natural gas. In light of low price projections for natural gas, steam reformation is likely to remain the primary production method for hydrogen for several decades.

[6] R. Werpy, D. Santini, A. Burnham, and M. Mintz, Natural Gas Vehicles: Status, Barriers, and Opportunities, ANL/SD/10-4, Center for Transportation Research, Energy Systems Division, Argonne National Laboratory, ANL/SD/10-4, August 2010.

depending on specific design and materials.[7] These blends are available commercially today and have been used successfully in demonstration projects. Blends of 20 percent by volume hydrogen are often marketed under the trade name Hythane; while blends of 30 percent by volume hydrogen are marketed as hydrogen-compressed natural gas, or HCNG.

Hydrogen-enriched natural gas can potentially meet tougher emission standards without requiring the installation of expensive exhaust after-treatment devices. Hythane has been shown to maintain fuel efficiency and reduce emissions of NOx in a conventional natural gas engine without imposing major conversion costs.[8] Modified natural gas engines operating on HCNG have been shown to meet strict NOx standards without fuel efficiency losses.[9]

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[7] Werpy, et al, 2010.

[8] Del Toro, A., M. Frailey, F. Lynch, S. Munshi, and S. Wayne, 2005, *Development and Demonstration of Hydrogen and Compressed Natural Gas (H/CNG) Blend Transit Buses: October 15, 2002 – September 30, 2004,* National Renewable Energy Laboratory Report NREL/TP-540-38707, http://www.afdc.energy.gov/afdc/pdfs/38707.pdf.

[9] Kramer, D., and J. Francfort, 2003, *Low-Percentage Hydrogen/CNG Blend Ford F-150 Operating Summary*, Idaho National Laboratory Report INEEL/EXT-03-00008. http://avt.inel.gov/pdf/hydrogen/f150lowpercentreport.pdf.